Status of eRD17: DPMJetHybrid 2.0

A Tool to Refine Detector Requirements for eA in the Saturation Regime

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28-January-2016

***-co-PIs**

New (official) collaborator

Lead author: Zheng, Aschenauer, Lee, EPJA 50 (2014) 189
"Determination of electron-nucleus collision geometry with forward neutrons",

Main coder: DPMJetHybrid

Baker

Aschenauer

Lee

Liang Zheng

Improves our chances of publishing results sooner rather than later

eRD17 in a nutshell

- Forward detector/IR design is happening NOW
  - MEIC aims for hermeticity on principle.
  - eRHIC relies on simulated measurements.
- DIS Models for eA have a serious deficiency.
  - Missing multinucleon recoil from k_T (aka Q_s)
  - We don't really know how complete the forward coverage needs to be.
- Upgrade DPMJetHybrid to include known effects
- Simulate a couple of key measurements.
- Phase I of project in FY2016: $32,000
- Phase II in FY2017: $33k ?

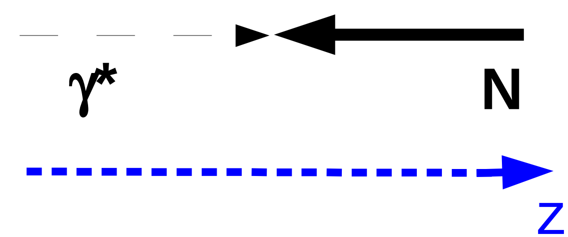
Outline/Summary

- New Collaborator
- Progress on Goals
  - Physics 1: Measuring intrinsic k_T in eA
  - Physics 2: Improving centrality (b & d) tagging
  - (Tech. 1: Multinucleon k_T recoil for low x in eA)
  - Tech. 2: Improve underlying ep (en) model.
- Feedback from potential user community
  - Centrality tagging should be #1
- Project timetable (1/4-7/19, 2016) & status
  - Just getting started. Phase 1 done by July.

Physics Goal 1: Intrinsic k_T

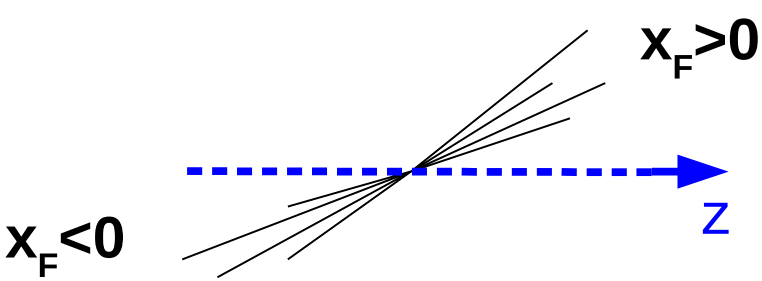
Consider the hadronic center of mass (HCMS) frame

γ^*N frame (for ep or eA)



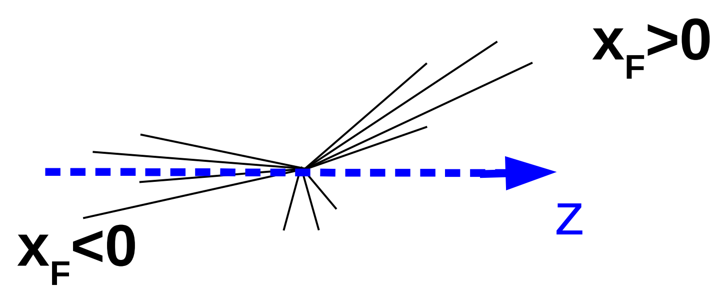
$x_F = 2p_z/W$

Intrinsic k_T at high $|x_F|$.

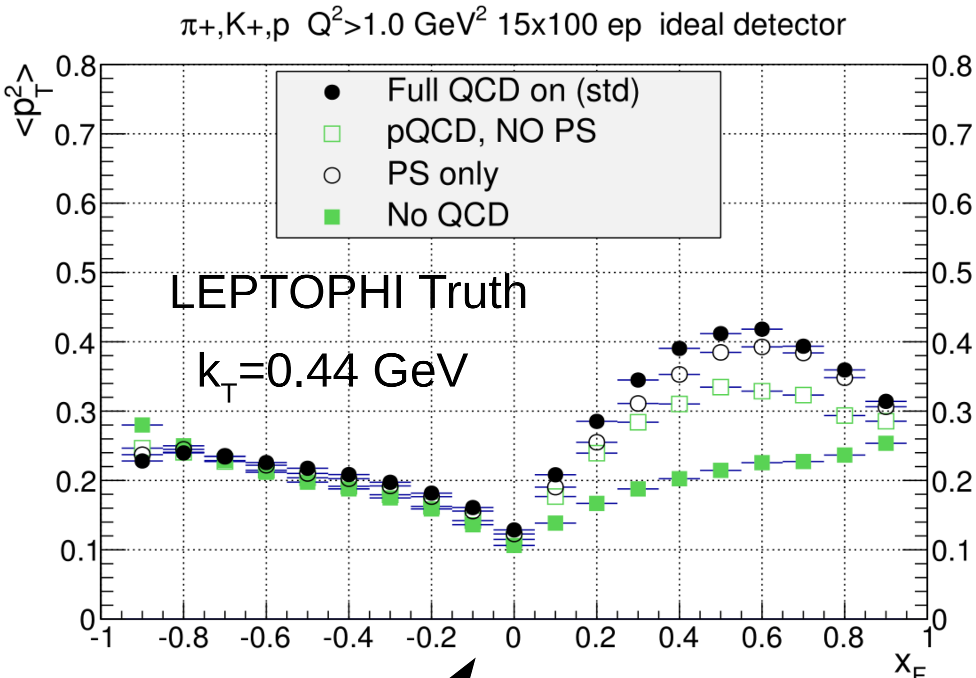


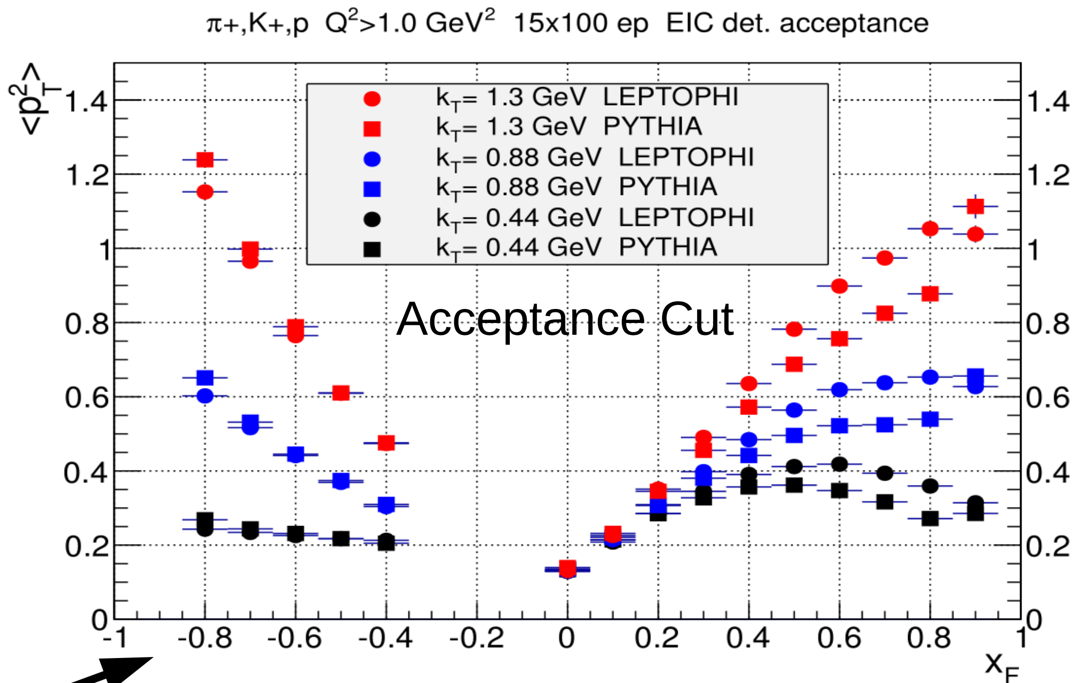
HCMS frame

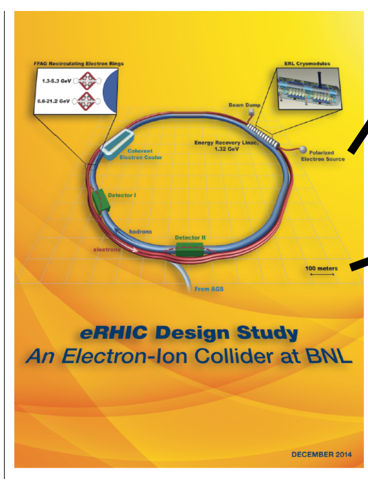
QCD radiation primarily shows up at $x_F \geq 0$



For ep, we can measure k_T at EIC







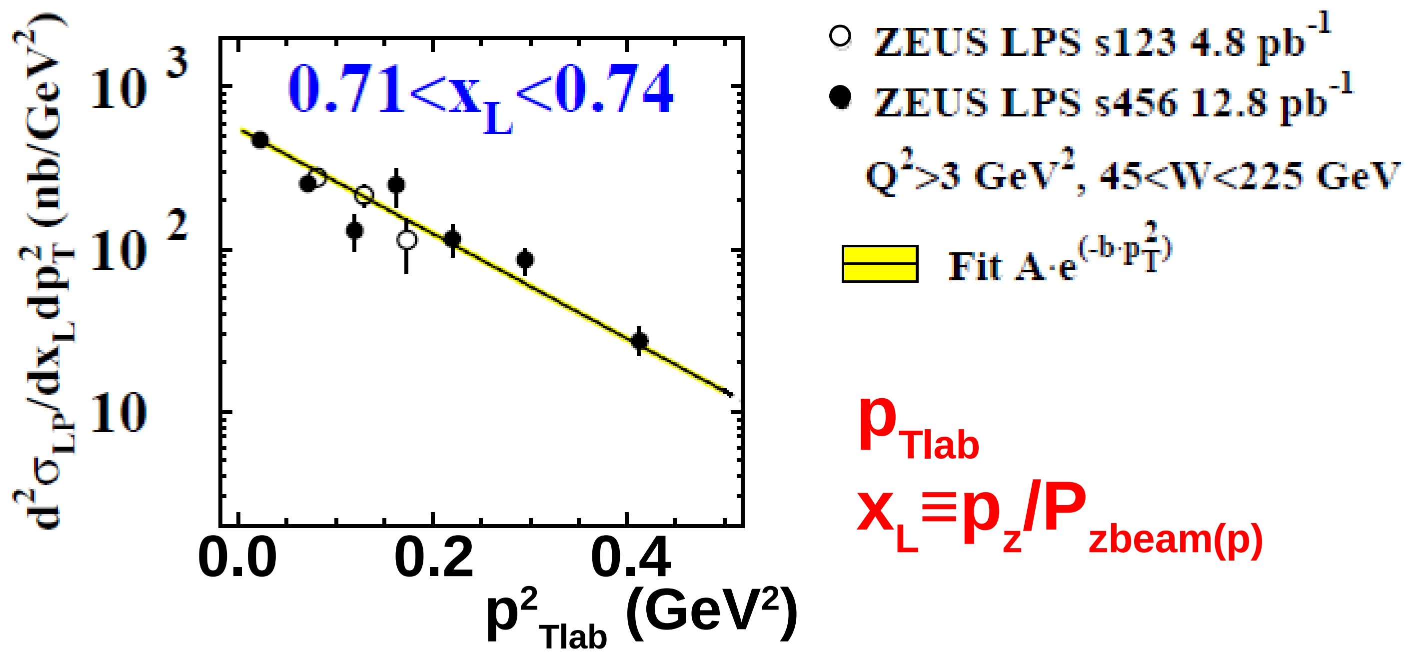
LEPTOPHI based on LEPTO 6.5.1
PYTHIA is PYTHIA 6.4

Detector Requirements:
Detection to η of 5
+ Roman Pots for forward protons

ZEUS used lab variables

ZEUS kinematics:
27.5 x 820 GeV e^+p
$Q^2 > 3$ GeV^2
45 < W < 225 GeV

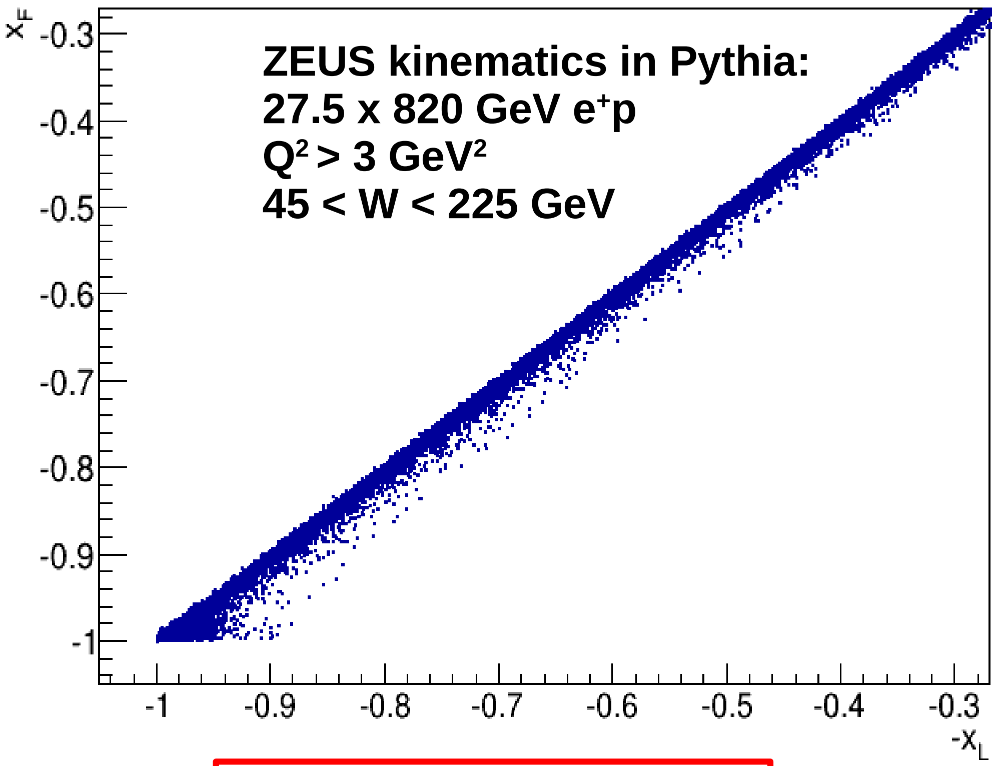
ZEUS, JHEP 06 (2009) 074

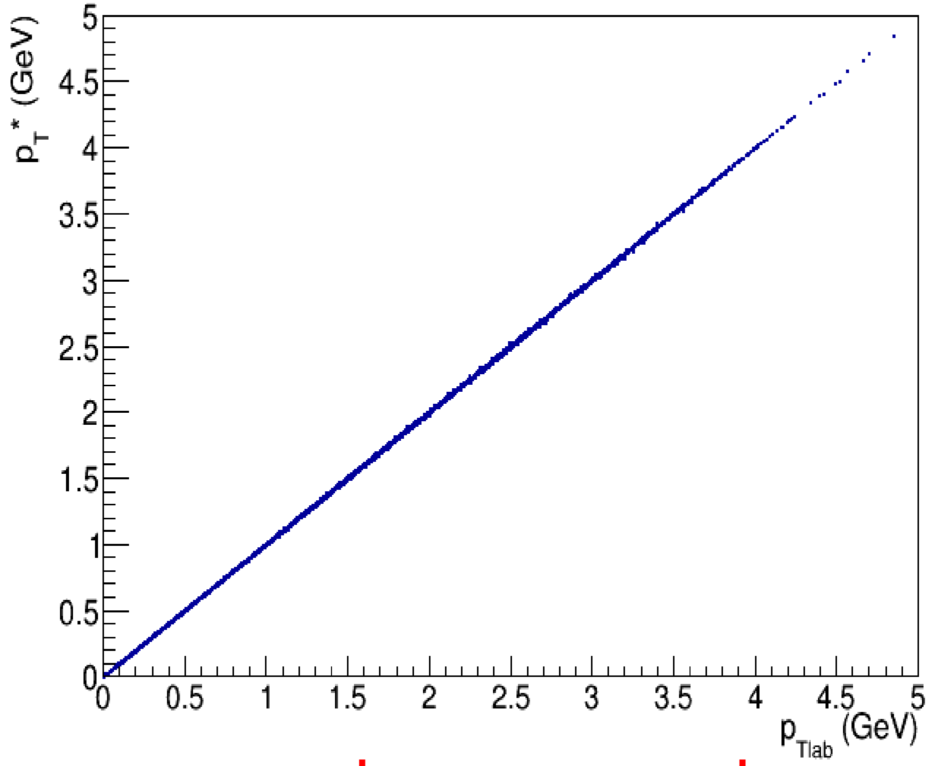


p_{Tlab}
$x_L \equiv p_z/P_{zbeam(p)}$

I wanted HCMS:
p_T^* (w.r.t. γ^*) and $x_F \equiv p_z^*/(W/2)$

Comparing lab frame and HCMS



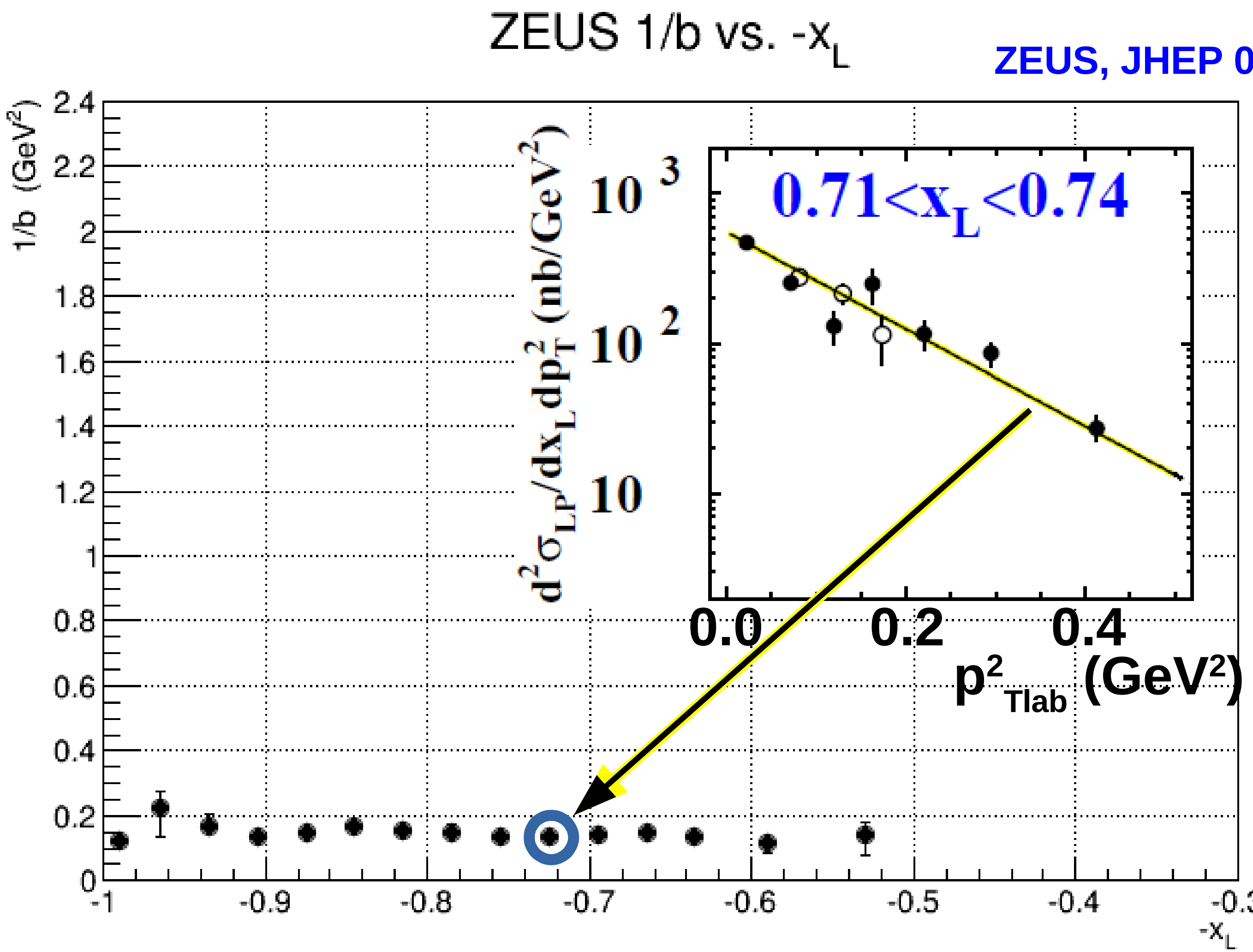


$x_L \equiv p_z/P_{zbeam}(p) \sim -x_F$

$p_{Tlab} \sim p_T^*$

This works because $q^\mu << P^\mu$ in lab
(at HERA & also EIC)

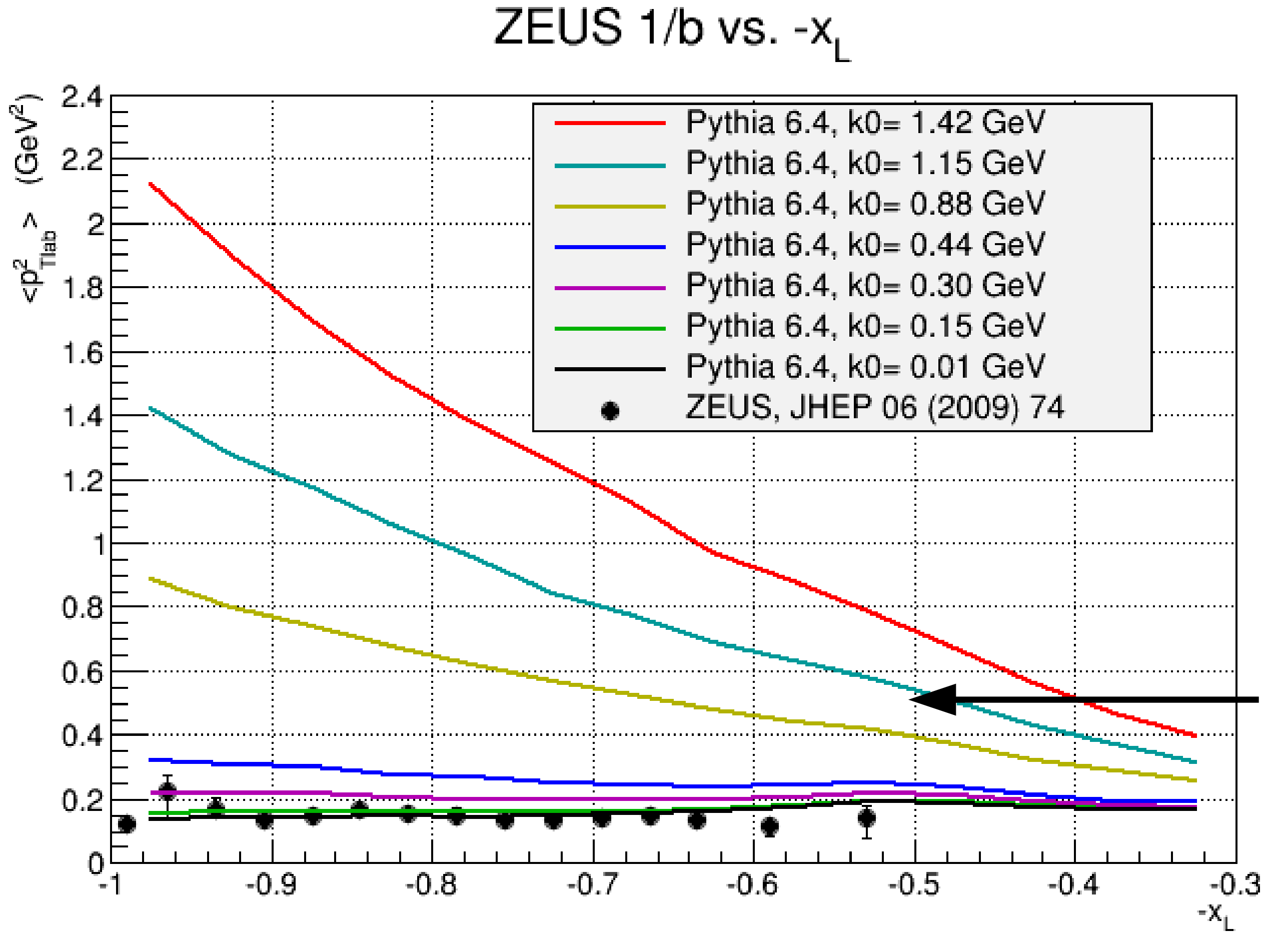
Laboratory “seagull” from ZEUS fits



$\langle p_T^2 \rangle = 1/b$ from fit

$x_F \approx -x_L$

Laboratory “seagull” from ZEUS



Pythia 6.4.28
EIC/BNL version

$k_0 = k_T^{rms}$ = PARP(91)

Default = 2.0 !

$\boxed{\mathbf{k_0 \neq 1.42\ GeV}}$

$k_0 \approx 0.01$ GeV

PROOF POSITIVE: The beam remnant jet is not contaminated by “QCD” effects

For more details see:
https://conferences.lbl.gov/event/56/session/8/contribution/40/material/slides/0.pdf

Phys./Tech. Goals #2 -A better Pythia for a better centrality tagging

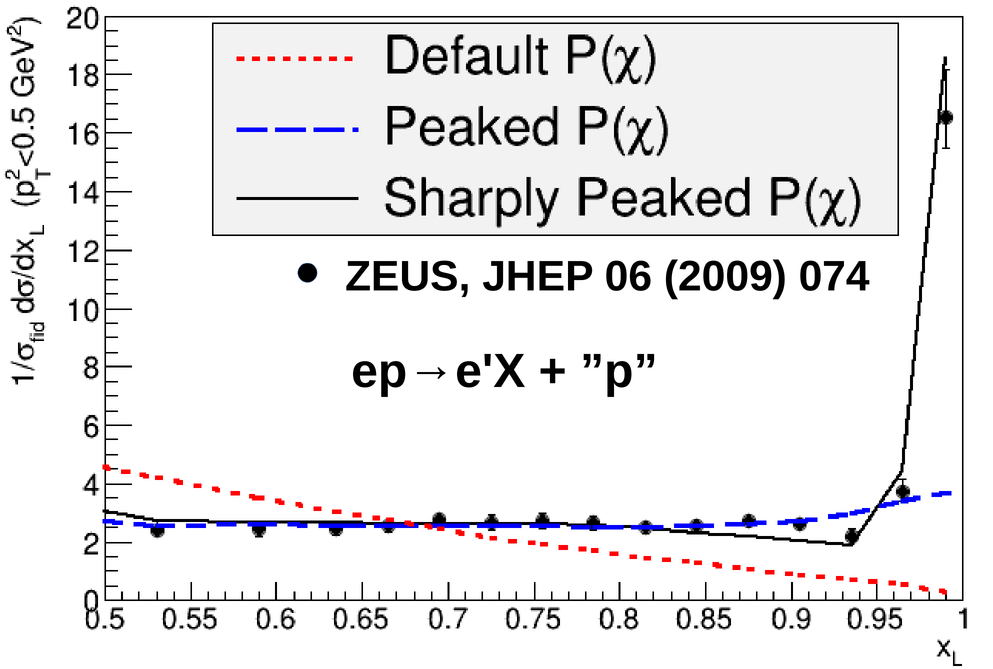
Non-trivial beam remnant clusters fragment into diquark+meson or baryon+quark. The p_L fraction carried by baryon/diquark is called χ.

We tuned $P(\chi)$ to better match ZEUS data. <u>More forward particles.</u>

	MSTP(94)	PARP(97)	$P(\chi)$
Default	3	-	Frag. function
Peaked	2	9	$10(1-\chi)^{9}$
Sharply	2	75	$76(1-\chi)^{75}$

We also lowered k_T to better match ZEUS data. <u>More forward particles.</u>

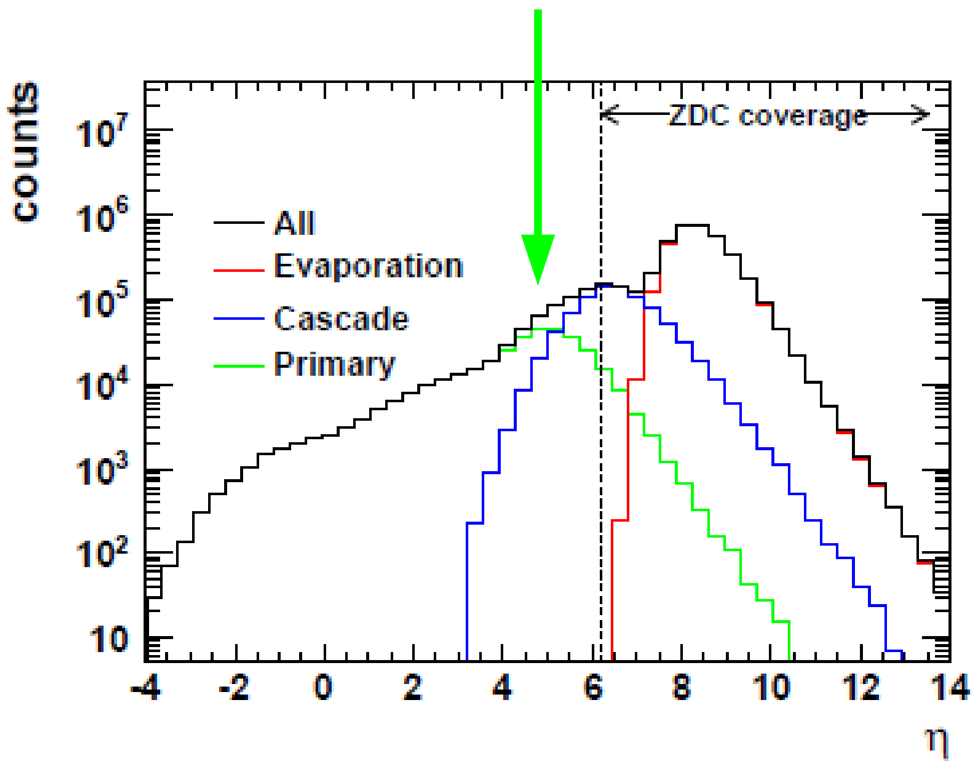
σ_{fid} = σ for h+ $0.5<x_L<0.89$, $p_T^2<0.5$ GeV^2



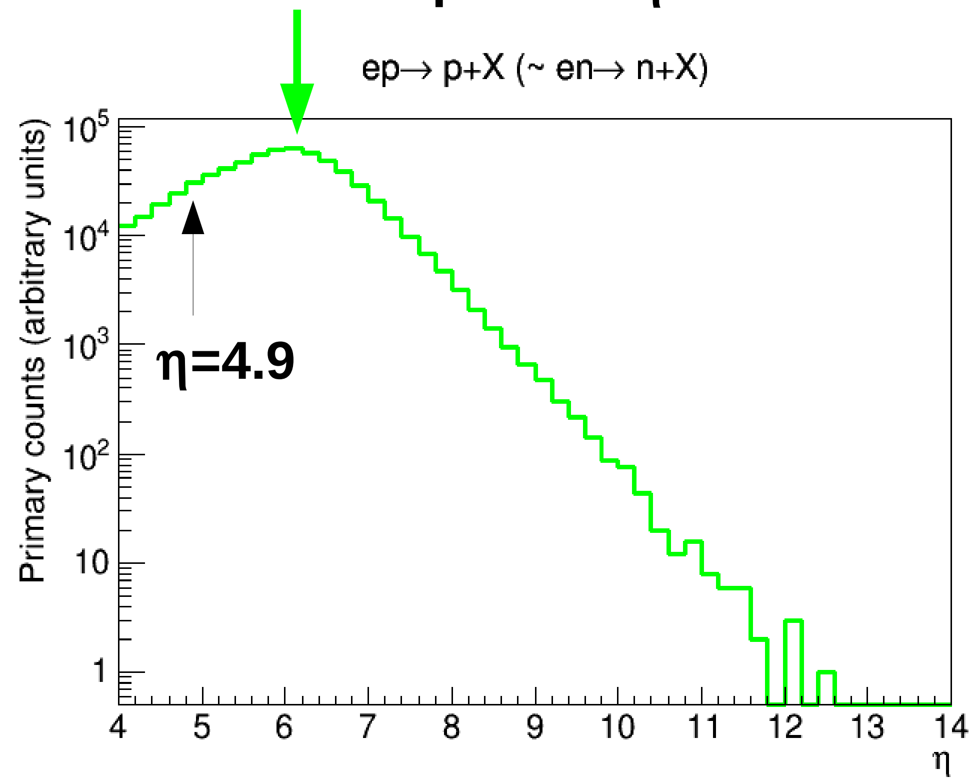
NOTE: Seagull plot is NOT strongly affected by $P(\chi)$.

Effect of Pythia tuning

DPMJet eA primary neutrons peak at η=4.9



Tuned Pythia ep→p (en→n) Primaries peak at η=6.1



Primaries, and therefore also cascade particles, will shift forward.

Progress on Goals

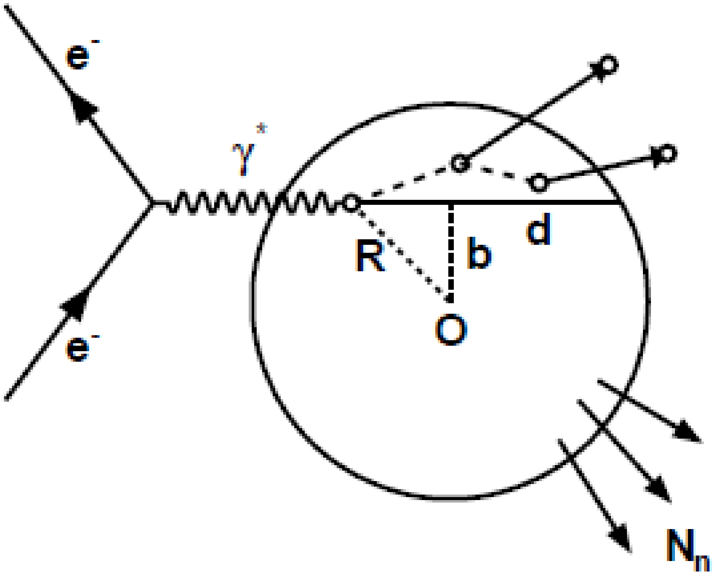
- Physics 1: Measuring intrinsic k_T in eA
  - Showed using ZEUS data that beam remnant recoil works for ep – no QCD contamination.
- Tech. 1: Multinucleon k_T recoil for low x in eA
  - Nothing new to report.
- Physics 2: Improving centrality (b & d) tagging
- Tech. 2: Improve underlying ep (en) model.
  - Working on improved Pythia tune

Feedback from potential users

- BNL crew already involved. Reach out to JLAB user community.
- EIC R&D Meeting (7/2015)
  - already lots of discussion.
- JLAB EIC Software Meeting (9/2015)
  - Elke: *Monte Carlo Generators for EIC* included eRD17 and it was discussed in the questions.
- EICUG meeting (1/2016)
  - Charles Hyde(!) - *Forward Tagging With the EIC@JLab Full Acceptance Detector* mentioned eRD17
  - Matt Sievert responded that tagging events with small d from the “back” of the nucleus would be very valuable for Orbital Angular Momentum studies in eA. Avoids rescattering.
- Next Generation Nuclear Physics with JLab and EIC (2/2016)
  - Baker invited to talk about centrality tagging in eA (plans)

Main message received from users

- Centrality tagging and forward detection is timely and of interest. Perhaps higher priority than the more difficult k_T in eA.
- For Charles and for Matt (and many physics topics), the distance traveled in the nucleus after first interaction (d) is more important than b. (Good! d is easier!)



Updated Timetable

- Project partially funded. Phase I in FY2016 Phase II deferred to FY2017 proposal cycle.
- Phase I timetable now: **Jan.4-July 19, 2016**
  - April 29 – Release beta version
  - July 19 – Release official version (Phase I)
- Phase I – simplified first step
  - Only 1 DIS/event to simplify color connections
  - Quick tune of components (like Pythia)
- Phase II will be a more thorough simulation.

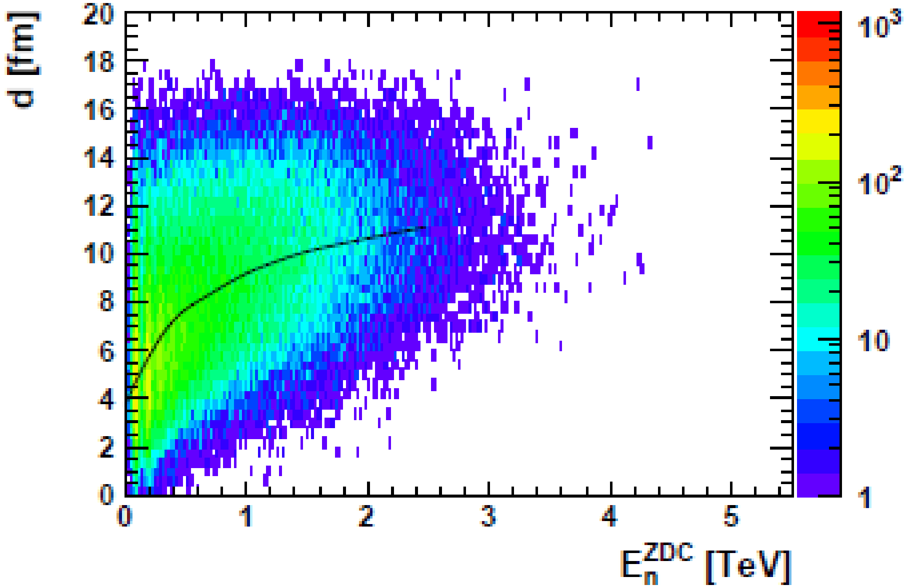
Summary

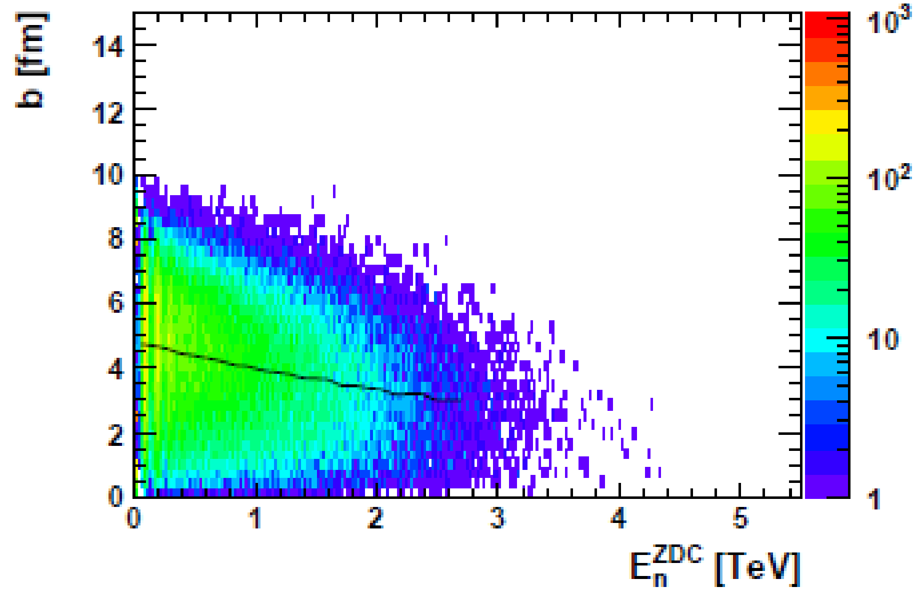
- Phase I Project timetable: 1/4-7/19
  - Just getting started
- New Collaborator
- Progress on Goals
- Feedback from potential user community
  - Definite interest esp. in centrality tagging.
- Looks good. Phase 1 should be done by July.

Backup Slides

Measuring d is easier than b

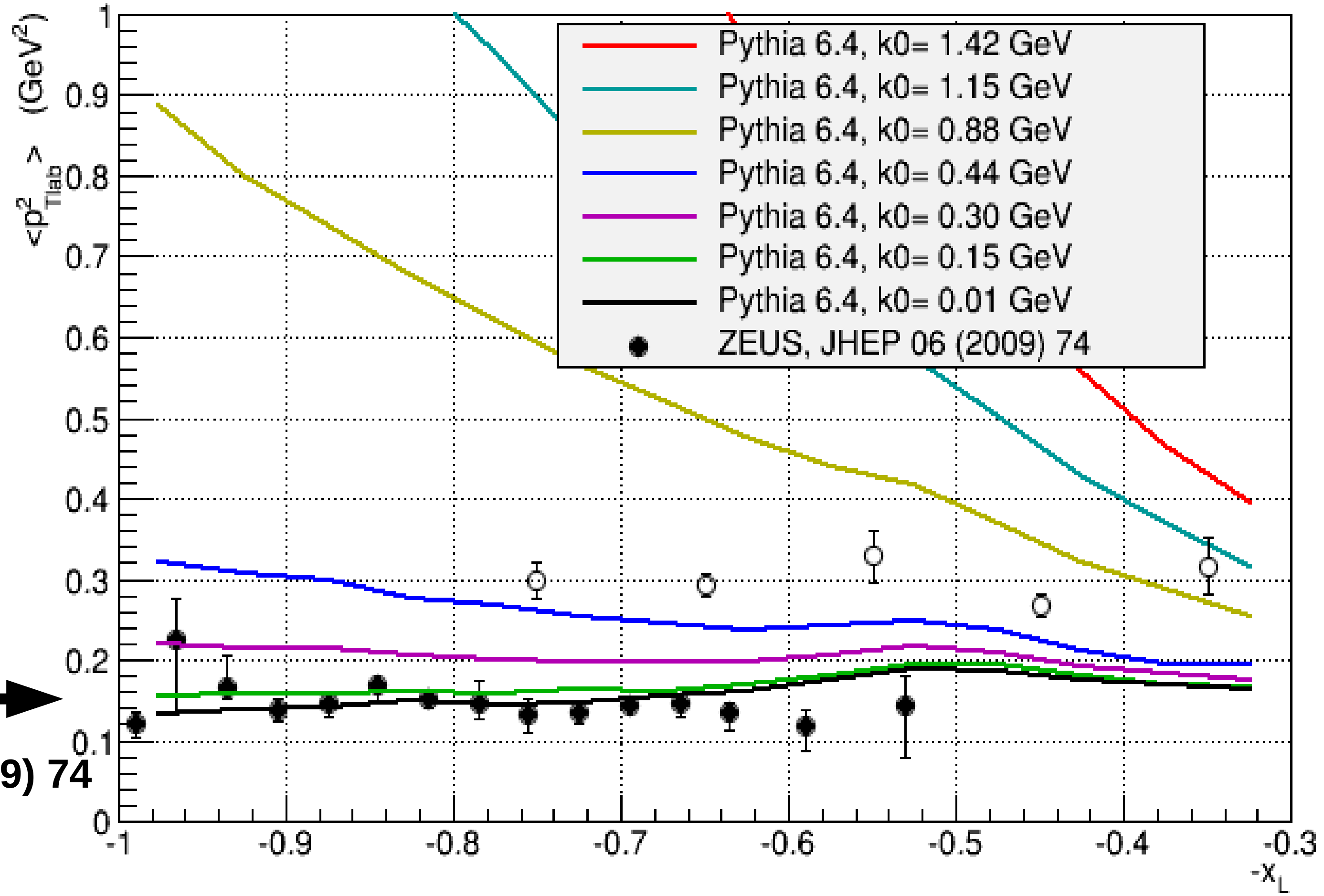
Zheng, Aschenauer, Lee, Eur.Phys.J.**A50** (2014) 189





Zheng, Aschenauer, Lee EJPA 50 (2014) 189

Hadron $<p_T^2>$: ZEUS = ½ EMC



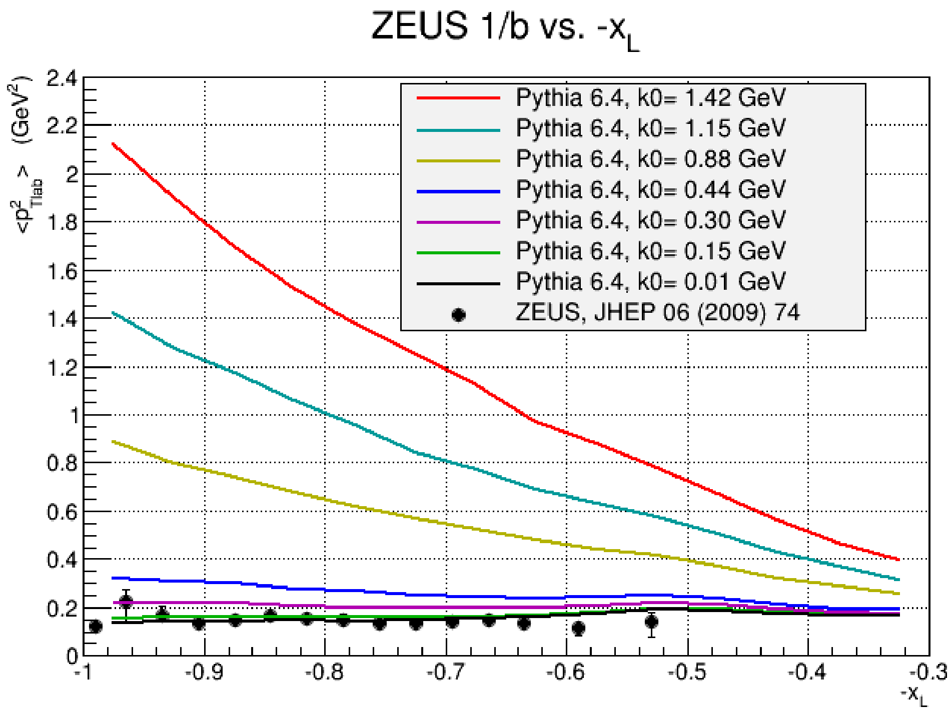
ZEUS
JHEP 06 (2009) 74

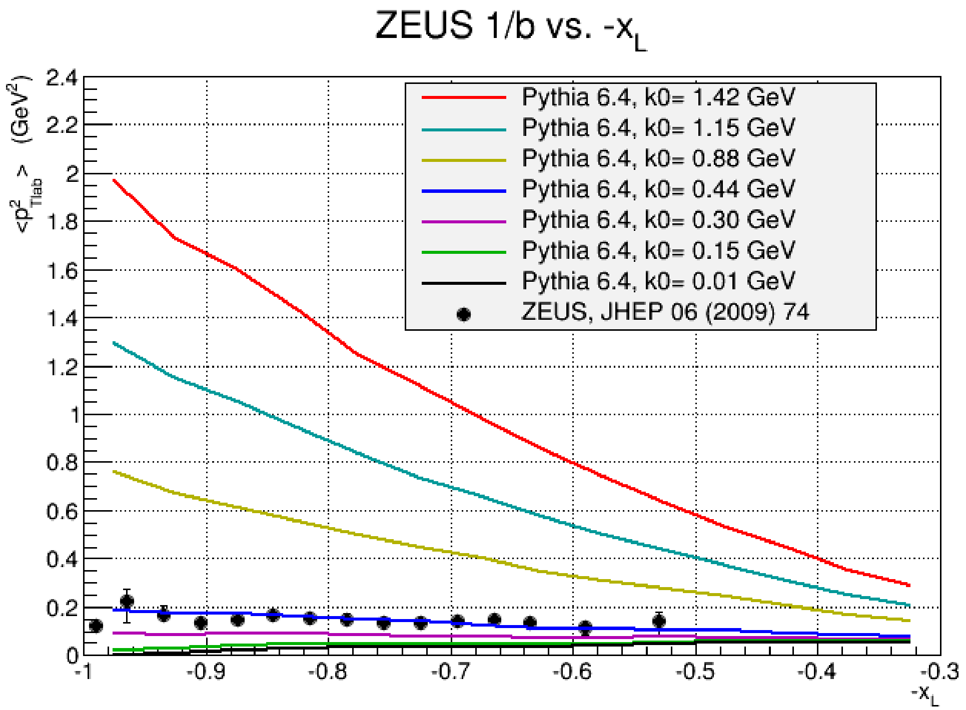
EMC
from
ZPC 36 (1987) 527

What is happening?

- Intrinsic k_T could actually depend on W (or x_{Bj})
  - Sea vs. valence quarks vs. gluons
- Non-gaussian tails could cause the discrepancy due to limited ZEUS acceptance.
- Fragmentation (and cluster breakup) p_T could depend on W(?)
- EIC can resolve this!
  - Extended range in beam energy and (x,Q^2)
  - Flavor-tagging events
  - Correlations to distinguish fragmentation p_T & k_T

Fragmentation p_T vs intrinsic k_T



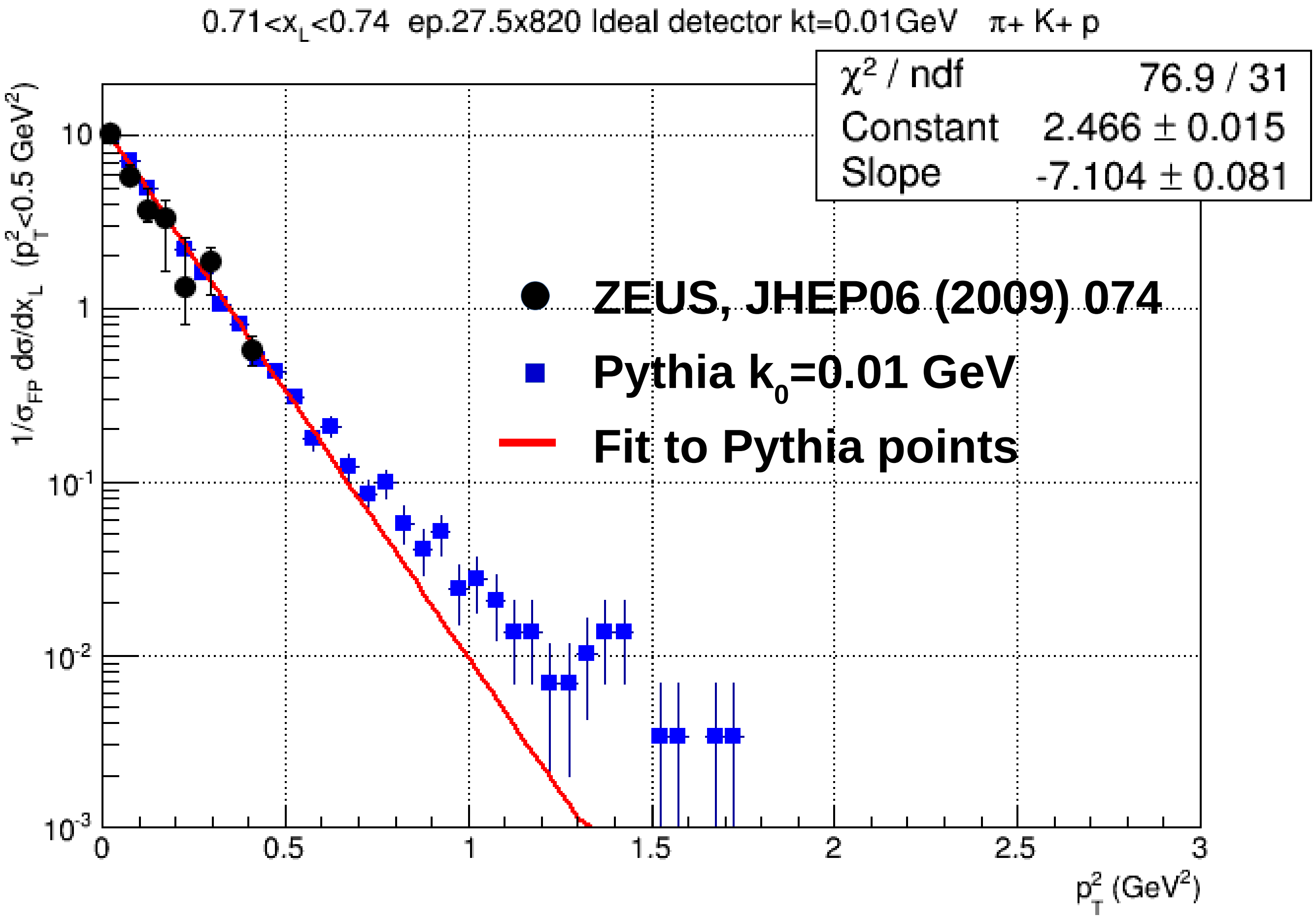


PARJ(21)=0.36 GeV (default) =
Fragmentation p_T AND
Beam remnant cluster breakup p_T
Data favors k_0=PARP(91)=0.01 GeV

PARJ(21)=0.01 GeV (TINY!) =
Fragmentation p_T AND
Beam remnant cluster breakup p_T
Data favors k_0=PARP(91)=0.44 GeV

But fragmentation decreasing with W is weirder than k_T decreasing with W

ZEUS's acceptance is limited

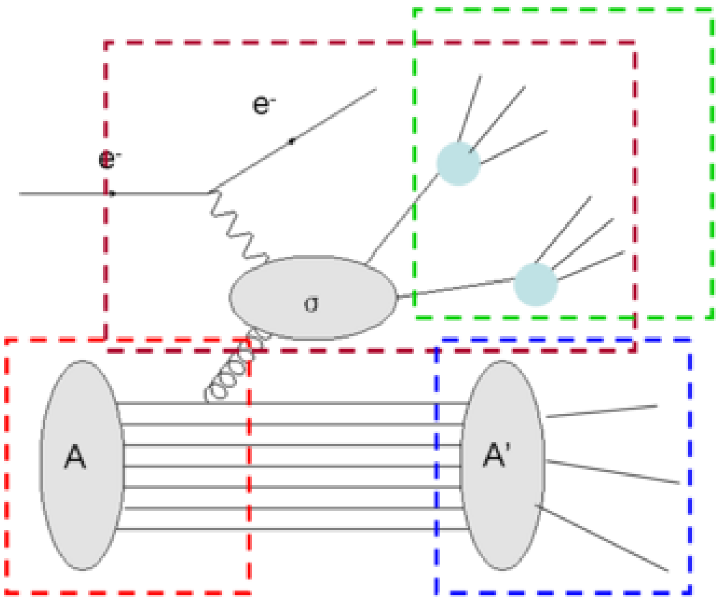


EMC used a streamer chamber and a fixed target – nearly complete acceptance.

Non-gaussian tails For $p_T^2 > 0.5\ \mathrm{GeV}^2$ could explain $k_T(\mathrm{ZEUS}) < k_T(\mathrm{EMC})$

What about eA? DPMJet-Hybrid (1.0)

From: https://wiki.bnl.gov/eic/index.php/DpmjetHybrid



A hybrid model consisting of DPMJet and PYTHIA with nPDF EPS09.

Nuclear geometry by DPMJet and nPDF provided by EPS09.

Parton level interaction and jet fragmentation completed in PYTHIA.

Nuclear evaporation (gamma dexcitation/nuclear fission/fermi break up) treated by DPMJet

Energy loss effect from routine by Salgado&Wiedemann to simulate the nuclear fragmentation effect in cold nuclear matter

“One thing to be mentioned for the case to run PYTHIA in DPMJET is that only **one nucleon in the nucleus** will be picked as a target nucleon in the collision.”

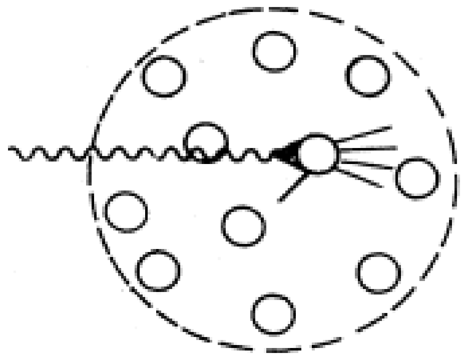
If valid, looking for Q_s in eAu would be easy. Just measure k_T recoil in ep & eAu.

eA: Basic Quantum Mechanics

$\hbar=c=1$ $\quad$ $r=0.88$ fm $\quad$ $1/(2Mr) = 0.12$ $\quad$ $\Delta p_z \Delta z = 1/2$

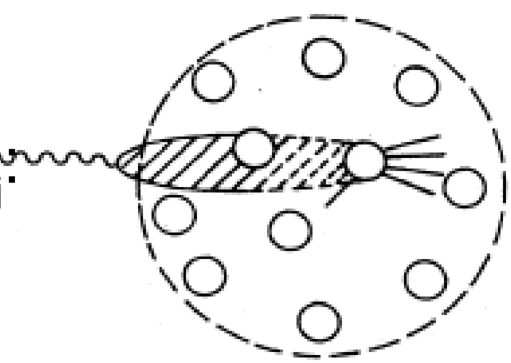
Bauer, Spital, Yennie, Pipkin
Rev. Mod. Phys. 50 (1978) 261

High x_{Bj}:



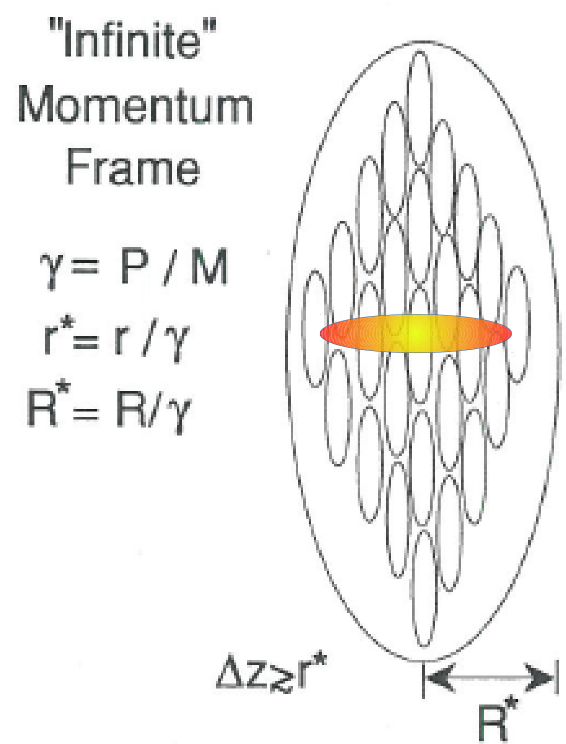
Nucleus Rest Frame (b)

Low x_{Bj}:



(c)

$\boxed{\lambda_h/r \approx 1/(2Mxr) = 0.12/x_{Bj}}$



$p_z^{quark} = Mx\gamma$

$\Delta z = 1/(2Mx\gamma)$

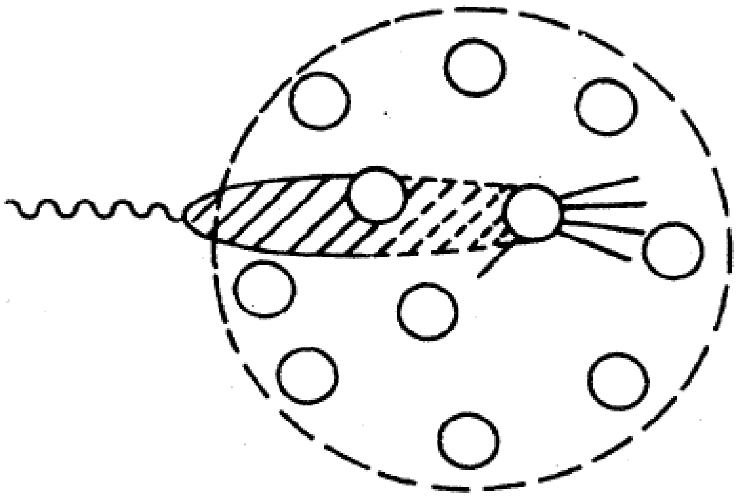
$$\boxed{\begin{aligned}\Delta z/r^* &= 1/(2Mxr)\\ &= 0.12/x_{Bj}\end{aligned}}$$

For x_{Bj}<<0.12, parton wavefunctions and/or interaction cannot be localized.

Impact on eA Forward Physics I

Most of the complications in saturation theory are in predicting the dependence on x, Q^2. With Glauber, we can make simple map:

$F_2^A/F_2^N(x,Q^2)$ ⟷ σ_{dipole} ⟷ $P(N_{coll},b)$



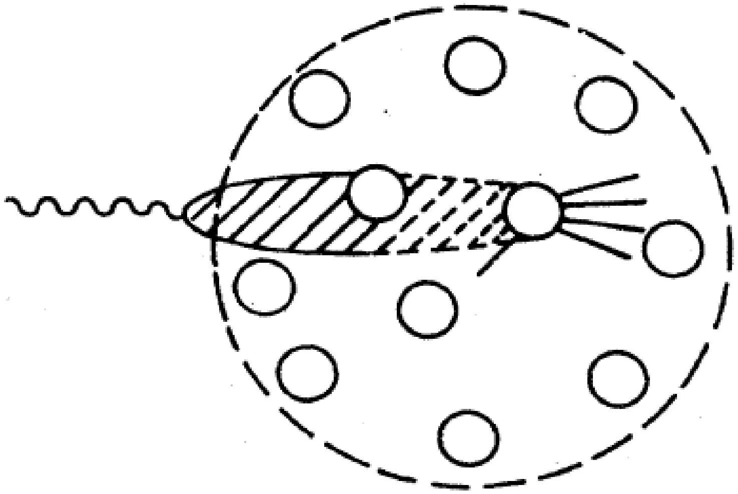
Direct measurement of k_T recoil is more challenging as it is shared between nucleons and/or nucleon remnants.

It may not be enough to sample forward nucleons,

We PROBABLY need to measure most or all of them.

And maybe correlate them with current monojets

Impact on eA Forward Physics II



(c)

Centrality measure for eA in order to look for enhanced saturation at b~0 may be EASIER due to extra recoiling nucleons and significant enhancement of intra-nuclear cascade.

In the case of saturating eA, it may not be enough to just measure (very forward) evaporation neutrons.

We PROBABLY can learn more by including the more modestly forward protons and/or neutrons.

Let's model this and find out!!